UNIFIED EVALUATION CRITERIA SYSTEM FOR SELECTION OF MOST PREFERABLE MODE, ROUTE AND MEANS OF TRANSPORTATION FOR OVERSIZED AND SUPER HEAVY CARGOES

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Abstract. In case of planning transportation of Oversized and Super heavy Cargo (OSSHC) we always meet two fundamental constrains – the time of completing the task and the financial costs of implementation. Also, the decision-making process should be as much as rational, uncomplicated, efficient and inexpensive. The importance of fundamental constrains mentioned above could vary because of specific circumstances impacting the decision maker. The essence of the Unified Criteria System (UCS) is to create a possibility to recalculate time and financial cost values into the Unified Criteria Unit. In case of correct access, the evaluation process is implemented comparing summed amounts of criteria points of each evaluated variant including means of transport, route, etc. The importance of findings is that UCS allows us to assess objectively huge number of variables (more than 50) concerning the process of transportation, including infrastructure improvement, legal, social obstacles, etc. without the time and money consuming extensive calculations and this empowers the decision maker to evaluate qualitatively and quickly choosing the most preferable alternative. The work deals with the possibilities of transportation of super heavy and oversized goods by road vehicles, railways, inland waterway vessels and trans-shipping of the cargo in Klaipėda State Seaport as well as application of the aforementioned modes of transport in multimodal transportation operations. Potential problems that may impede transportation or make the carriage practically impossible have been also assessed, variants of solutions of the problems are also provided.

Keywords: oversized and super heavy cargo, criteria systems, transportation, over-standard cargo.

Introduction

The problem of transportation of Oversized and Super heavy Cargo (OSSHC) occurs when solving problems of economic development. In spite of most industrial equipment manufacturers are struggling to align the components of their production with basic gauge and weight transport standards, this is not always achieved because of specifics of technology. Various technological equipment, such as chemical industry equipment (e.g., reactive columns), nuclear reactor components, wind electric-power turbines, etc. quite often exceed these standards, therefore, OSSHC transport tasks are to be solved in order to locate industrial objects in the planned places that are suitable for economic conditions. It is worth pointing out that similar issues also arise in the field of military logistics, since military ammunition also often exceeds the standard transport gauge and/or mass limits.

The solution to the OSSHC transportation problem is started from the choice of the mode, route, type of transportation that would be most suitable for transportation speed, cheapness, environmental impact and so on to be made. Unfortunately, doing so is not easy due to the large number of factors and diversity affecting the rationality. In order to calculate the cost of a single transport mode, it is necessary to estimate both the expected future transportation time and the route adaptation, i.e. improvement-preparation time, both direct and indirect costs involved. Often transportation means suitable for transportation could be rented, relocated or even specially made. Therefore, additional costs arise because of this reason and should be taken into account.

As an important part of modern logistics, oversize cargo transportation refers to a series of applications of suitable vehicles, ships, and other transportation tools, using the corresponding safety measures and the necessary administrative permission, via roads, waterways, railways, and other transportation methods, from the place of departing to the place of delivery [1].

Oversized or heavyweight cargo is cargo the actual dimensions or weight of which exceed the maximum allowable values established in the countries through which it is transported. Transportation of oversized cargo is an extremely complex process and is regulated by the rules for the transportation of oversized and especially heavy cargo, which may vary depending on the country through which the goods are transported [2].

Analyzing the literary sources devoted to the problems of transportation of heavy and oversized cargo (OHC), it can be stated that there is no single and precise definition of heavy and/or oversized cargo. The lack of a single definition of this type of cargo is due to the diversity of the goods themselves and the vehicles that carry them, which include heavy lifting devices, too wide, too high or too long, exceeding the dimensions of the vehicle, loads and/or loads, the mass of which exceeds the load on the axle of the vehicle [3]. Over-standard cargo (oversized, non-standard, over-metric) is distinguished by its non-standard weight, size and shape that differs from standard loads. Special means of transport are needed to move this type of cargo, as well as handling machines that can carry the load [4]. In a number of cases, special vehicles and special structures or facilities for working with KFOR are manufactured for the transportation of such goods.

Their transport is a highly time-consuming and complex undertaking, frequently having impact on the condition of road infrastructure, urban greenery and traffic congestions, which are all elements of the city inhabitants' quality of life [5]. Transportation of oversized and heavy cargo affects the entire transport system due to its sensitivity to any traffic jams, especially on city streets. As roads are improved, innovations are introduced that increase the safety of vehicles, but reduce the likelihood of passing non-standard loads. For technical, organizational and security reasons, transportation is carried out at night, when there is the least amount of conventional vehicles [6].

The following characteristics are important in determining OHC in all cases: cargo dimensions; cargo weight; parameters of the car with cargo; admissible loading of the car; allowable road surface on which the car with the load will move (road or rail) [4; 6].

In the majority of cases, standardization of the technology of transportation of Heavy Weight and Oversized Cargo (hereinafter – HW/OS cargo) is very complex. Solutions, which would allow delivering HW/OS cargo to the place of destination allocating minimum funding for the improvement of infrastructure, choosing the most appropriate mode of transport for such cargo or taking advantage of multimodal transportation, are necessary [7-9].

The geometric shape of the load is also very important, as it can adversely affect the static or dynamic stability of the vehicle [2; 4].

Along with the development of economy there is an increasing number of shipments that, due to their size, weight or specific character of carriage, require individual solutions [10]. Oversize-heavyweight cargo can be transported by a variety of traffic means: roads, railways, sea and inland waters. The choice of transport means depends on cargo parameters (height, width, length, weight) and transportation costs [2]. Oversize cargos include non-standard large and heavy indivisible cargos such as electric transformers, reactor vessels, windmills, airplane fuselage or nuclear power plant- which is usually a part of advanced infrastructural high priority energy and technology projects. Oversize transport often needs to travel considerable distance; in many cases, national borders have to be crossed. Mainly this is based on a different kind of transport, often on sea transport. There are some problems to solve in case of such kind of transport [3].

When transporting OHC – it is important to estimate the type of transport being chosen. This choice is determined by the physical possibilities (the reality of transportation options for a specific mode of transport, the quality of the infrastructure) and the type of transport costs. Available transport modes: maritime transport, inland waterway transport [11; 12], rail transport, road transport. The modes of maritime transport and inland waterway transport are the least sensitive to bulky and massive weight. 500 tons, 1000 tons or even larger loads are not a problem in maritime transport, as gauging 15 meters in width, length or height is also not a major problem and is usually considered a normal cargo in sea transport. Inland waterways have similar characteristics. Inland waters can only lead to height restrictions in case of crossing bridges. However, these cargo parameters become a serious problem in rail or road transport modes. This problem is further exacerbated by the immense pricing and heavy-duty taxation. The meaning of the charge is to compensate for the possible damage caused by heavy loads in the pavement or railways, as well as social damage, as disturbing normal transport activities.

One of the most important route design activities is the route selection. Route requirements:

- matching the load parameters;
- technically safe (i.e. the infrastructure allows transporting the oversize
- and heavyweight cargo safely);
- acceptable considering the distance:
- least time is spent in transportation;
- rational taxation of the oversize and heavyweight cargoes;

- cheap (i.e. ensuring the lowest transportation costs);
- making the minimum negative impact on the environment [3].

Oversize and heavyweight cargoes are usually transported using multimodal transportation way. It depends on the place where such cargoes are produced and where they should be used. The route for carrying oversize and heavyweight cargo is usually evaluated and designed individually. For this reason, the transportation process of oversize and heavyweight cargo becomes a problem, because investments for upgrading road transport infrastructure comprise a comparatively big part of the total project cost [13]. The task of transport decision makers is to find the key for suitable transport development and reduction of a negative transport impact [14; 15]. Therefore, it is necessary to create a criteria system as an instrument which allows evaluating sections of the route or the whole route for heavyweight and oversize cargo transportation. The system gives the possibility to choose objectively the most suitable sections of the route in existing road network.

This article contains a system of criteria, the basic principles of which are the cost of the route preparation and the shipment of cargo, and the time for the implementation of the above operations. Foreign researchers are also examining this problem, but their solutions are suitable for those areas where the road infrastructure is well developed [16; 17]. In our case, when designing a car route, it is necessary to re-design road sections or substantially improve them in practice. But it is important to be efficient in making the decision which route is the most preferable from the point of view of logistical capability, shortest time in making the route instrumental and financial efficiency. All mentioned aspects are unified as criteria points, evaluating them through nondimensional values.

Principles of unified criterion system

The purpose of the criterion system is to create an objective OHC transportation assessment tool, separate sections of the route or a universal rating system for the whole route. It allows to choose the most suitable road sections, the mode of transport and the means for each particular OHC cargo transportation, as well as compare the routes with each other. The term “most suitable” means the best compromise between the minimum time-consuming time (for the whole route preparation time and the delivery of the goods) and the minimum cost of money (the amount of direct transport costs, including the costs of heavy-weight reloading, if necessary, as well as additional costs, including special preparation of the route and vehicle for transportation and legal fees for allowances, local taxes, compensation, etc.).

The criteria design overview

In case of OHC transportation (according to the nature of the criterion), there are two categories of criteria:

Criteria for assessing the impact of consistently changing factors, for example. The distance of the road, with which the cargo transportation time increases, the price and the size of the charge for OHC.

The criterion category is the discretionary assessment of the influence of non-linear factors, for example: the weight of a carriageway. In turn, this category of criteria has two sub-categories:

Criteria for assessing the effects of interference on transport, varying with equal jumps, for example: if the weight of the carriageway (gross) reaches a threshold of 250 t, it can no longer be transported through bridges, and therefore a different alternative must be sought for its transportation through water bodies, valleys or other obstacles of this kind. The second “break” point for this criterion is 550 tons.

Criteria for estimating the impact of interference on traffic, by their nature, with marginal break points, when the transportation of cargo becomes practically impossible.

The objective of the detailed analysis is to select the best sections of routes for transportation of heavyweight-outsized cargoes that the transportation across them would require minimal expenditure and loss of time. The whole selection of sections of routes was performed following the criteria submitted: bridges, overpasses; culverts (inadequate strength); towns, settlements; turning radius; railway crossing roads; roads; gas pipelines, oil pipelines; length of route; transshipment into the road transport. As there are several clear turning points of some criteria, for example, the weight of cargo (up to 250 t and over 250 t), therefore it is expedient to submit various routes. It is clear that after preparation of the route of over 250 t, it will be possible to transport all the intended cargoes via it, however, the comparison of both variants allows to decide whether it is expedient to mount a route for heavier cargoes on the whole or to look for another alternative.

The following routes of super heavy and oversized cargo transportation have been analised and proposed:

1. carriage by road vehicles of cargo not exceeding 250 t on the route Klaipėda – Salantai – Road A11 near Plungė – Telšiai – Kuršėnai – Šiauliai – Pakruojis – Smilgiai – Panevėžys – Subačius – Kupiškis – Rokiškis – Zarasai – Visaginas;
2. carriage by road vehicles of cargo weighing 250 t – 1000 t on the route Klaipėda – Palanga – Salantai – Road A11 near Plungė – Telšiai – Kuršėnai – Šiauliai – Šeduva – Panevėžys – Subačius – Kupiškis – Obeliai – Zarasai – Visaginas.

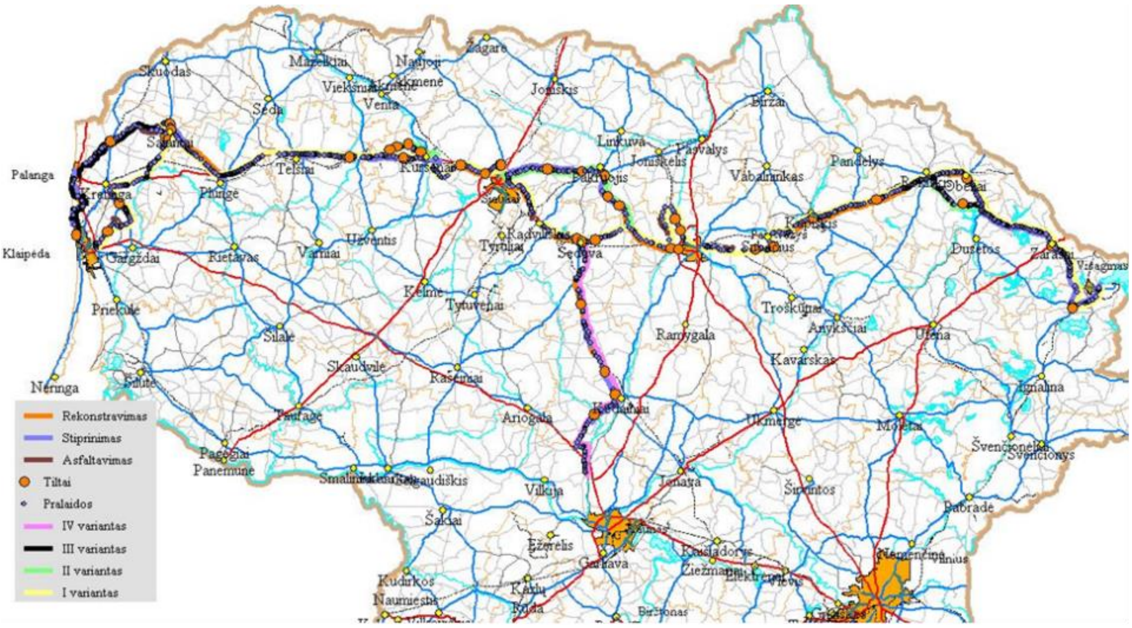

Fig. 1. **Super heavy-oversized cargo (over 250 t) transportation route Klaipeda – Visaginas**

The preferable route alternatives are seen on the map (Fig. 1) – blue and yellow dots present various critical factors of the road transport route, which are necessary to be taken into account.

Restrictions on the physical characteristics of the road – in this group, two criteria are foreseen to be related to: pavement and physical road surface quality assessment.

Influence of road section coverage on the cargo transportation speed (K_d) – this criterion is intended to compare the advantages of the route in different modes of transport (1). In the case of automobile route assessment, two alternatives to road segment criteria are distinguished: asphalt or gravel. These options allow to evaluate the speed of cargo movement on the route. The absence of a road section allows to evaluate the possibility of constructing a new road or looking for alternatives.

$$K_d = \frac{1}{V_{avg}} \cdot \in \begin{pmatrix} l_a \\ b \end{pmatrix}, l_a = [0,\ldots n], b = [0,\ldots n_1], \quad (1)$$

where K_d – numeric meaning of pavement characteristics;
l_a – asphalt pavement length of the route in kilometers;
b – gravel pavement length on the route in kilometers;
V_{avg} – speed average of carrying OHC in the analyzed mode of transport.

In the case of an inland waterway, this criterion has two extremes: satisfies the criteria or the route is inappropriate.

In the case of railway, this criterion may have four meanings, according to the categories of separate section of the road, which are specified in the Order of the Director General of Lithuanian Railway No. In-282.

Physical quality of road pavement at the moment of assessment – this criterion makes it possible to assess the suitability of the road pavement for cargo transportation and the need for one or the other actions required to ensure the quality of the road.

In the case of automobile route assessment, four alternatives are distinguished: when the route quality meets the requirements (the weight assigned to it is 0, because no additional actions are needed, so there is no additional cost and time consuming). Small improvements include the dismantling/installation of street partitions, street corridor reinforcement, road surface treatment with dolomite rubble and the like. Capital works – this criterion is of the highest importance at the time of evaluation and is intended to assess the development of such actions as the creation of a qualitatively new coating, the construction of a new road section, and the like.

In the case of inland waterways, this criterion has four alternatives, i.e. the quality required, the necessary cleaning of the section required for the removal of the stones in the section under consideration or the required depth of the section (2). The last three alternatives to this criterion are to be evaluated only if the development of the stretch is only required for a OHC carrier. The nominal depth ensuring the movement of vessels is guaranteed by the Inland Waterways Authority. If there is an unforeseen obstacle on the route in accordance with the Inland Waterways Directive, this obstacle must be removed within two days at the latest.

$$K_F = \frac{c+e+g}{d} \in \begin{cases} c, c = [0,...n] \\ e, e = [0,...n] \\ g, g = [0,...n] \end{cases} \tag{2}$$

where K_F – coefficient describing the possibility of transport mean application;
c – estimation of road construction and rehabilitation costs;
e – estimation of road construction and rehabilitation time;
g – need for further works, expressed in financial terms;
d – possible financial losses.

When applying a combinative way of outsized-heavyweight cargoe transportation, i.e. inland waterway transport – road transport, it is necessary to sail a distance as long as possible by inland waterway and to reduce a number of larger rivers, which would be necessary to cross by road transport as much as possible.

In case of rail, this criterion has two marginal values, i.e. the quality meets (weight of the criterion 0) or the cargo is not allowed to be carried.

Obstacles to the geometry of the road section – the term for the freight corridor is best suited to describe this criterion, which defines the parameters of the height, width and curvature of the shipment corridor.

In the case of both – in road and inland waterway tracking, the criteria have three alternatives: the radius of curvature meets the conditions for the carriage of goods.

Minor improvements to the route are necessary – this means small carriageway straightening works, a modest road deck propagation, and so on.

Major work would mean the major redevelopment of the road section. In the case of an inland waterway, minor improvements would imply a slight reduction in the range of the waterway through cleaning operations.

Capital works in this case would mean capital construction of the waterway strip.

The freight corridor in the section of the road part is too narrow (in the case of a waterway, this would mean a low waterway section width or the distance between the bridge supports); in the case of the road route the criterion has four alternatives: the width of the corridor satisfies the conditions for the carriage of goods.

Minor improvements to the route are needed – this means small road pavement improvements, small improvements (widening) of roadbed.

Major works would mean major redevelopment of the road section; option – problems cannot be solved rationally – it means that you have to choose another alternative to transport. In the case of an inland waterway, the width of the corridor satisfies the conditions for the carriage of goods; minor improvements would mean a slight increase in the waterway – fairway width through cleaning operations; capital works in this case would mean capital for the distribution of waterways; it is not possible to rationalize the problem – it is necessary to choose another alternative of transportation.

In the case of rail, this criterion has two limit values: the width of the corridor is satisfied, and the redundancies are not needed or unsatisfactory, which would mean that the cargo is not to be carried (3).

$$K_{geo} \in \begin{cases} h, h = [0,...n] \\ a, a = [0,...n] \\ r, r = [0,...n] \end{cases}, \tag{3}$$

where K_{geo} – coefficient describing the possibility of transport mean application because of geographical obstacles;
h – high of the transportation corridor for OHC;
a – width of the transportation corridor for OHC;
r – radius of the road curve.

The freight corridor on the section of the road section is too low (in case of a waterway, this would mean insufficient height between the water surface/bottom and the bottom of the arch arch); in case of road route assessment, the criterion has four alternatives: the corridor height satisfies the conditions for the carriage of goods; minor improvements are needed – this means small improvements over the road.

Major work would mean major redevelopment of the route; usually it is not possible to rationalize the problem – it is necessary to choose another alternative of transportation.

In case of an inland waterway, the height of the corridor satisfies the conditions for the carriage of goods; minor improvements would mean a slight increase in the height of the waterway, eliminating the height of the waterway limiting the small structures or temporarily rolling the inland waterway transport below the nominal waterline; capital works in this case would mean a capital shift in the waterway; it is not possible to rationalize the problem – the solution is to choose another alternative of transportation.

In the case of rail, this criterion has four limit values: the height of the corridor satisfies the conditions for the carriage of goods; minor improvements are needed – this means small improvements over the road; major work would mean major redevelopment of the route; it is not possible to rationalize the problem – it is necessary to choose another alternative of transportation.

It is necessary to analyze the perspective project of Rail Baltica, it is appropriate to envisage at least 2-3 railway overpasses (preferably in the northern part of Lithuania) with a height clearance of at least 10 m or car overpasses through which it would be possible to transport heavy loads on the territory of Lithuania.

The weight of freight to be transported – this criterion is important for assessing modalities of all types of freight transportation, but it has the least impact on inland waterway transport. This criterion makes it possible to assess the possibilities of using stevedoring tools, the speed of cargo transportation and route selection.

This criterion can acquire four values: up to 100 t – this factor is due to the possibilities of using existing load handling tools; cargo from 100 t to 250 t – this factor is important in assessing the car route, as it makes it possible to use existing bridges without improvements; loads from 250 t to 550 t – this factor has an impact on the assessment of both car and rail transport routes (4). Cargo loads above 250 t become particularly critical for road sections with bridges; cargo over 550 t – in case of necessity to carry such type of cargo, the cost of transportation of freight and the number of additional problems related to cargo transportation procedures increase in particular.

$$K_{sv} = \frac{(t_{kr} \cdot d) + k}{d} \in \begin{cases} t_{kr}, t_{kr} = [0,...n] \\ k, k = [0,...n] \end{cases}, \tag{4}$$

Obstacles to legal (including environmental) requirements. In the case of road route assessment, the criterion has four alternatives: the need for urban/settlement passage – this criterion relates to the rules for transporting large and large loads across the metropolitan areas or for the needs of route development in those areas; the need for passage of protected areas means the assessment of obstacles in case of need for improvement of the route in these territories.

In case of an inland waterway route, the criterion assesses the needs for crossing of protected areas, the installation of cargo reloading points, and the installation of temporary storage of cargo. In the case of railways, this criterion has four alternatives: the need for urban/settlement passage; the need for passage of protected areas; the need for cargo reloading sites; the need for the temporary storage of cargo.

Accessibility for the transport of goods – this criterion has three alternatives common to all modes of transport concerned: i.e. vehicles located in Lithuania, vehicles located in foreign countries, or the need to create a new vehicle that would ensure the transportation of bulky or heavy goods.

The need for freight accumulation – this criterion is determined by the freight logistics scheme. Accumulation of loads is rational in the case of large or limited costs of delivery of bulky and heavy goods. In this case, it is expedient to accumulate cargo and transport them simultaneously.

The intensity of traditional traffic in the road section under consideration – this criterion has three alternatives common to all modes of transport in question and, at the same time, aims to assess the social consequences of transport of large loads and heavy loads.

Total route length – this criterion belongs to the category of gradually changing variables. Estimated length of the route in kilometres. In different modes, the weight of this criterion is different because of the difference in average freight speed and the cost of transport per kilometres.

Obstacles because of bridges/dams along the route.

Insufficient bridge capacity – this criterion may have five meanings (5): the lift capacity of the bridge satisfies the conditions for the carriage of goods; in this case its weight is 0; requires a metal ramp or bridge reinforcement; necessary for the installation of a pass; construction of a new bridge is needed; rational solution to the problem is impossible – it is necessary to use another mode of transport.

$$K_d = \frac{(t_s \cdot d) + k}{d}, \tag{5}$$

where K_d – waterway obstacles coefficient;
t_s – time of improvement of the dam or lock;
d – possible financial loss;
k – constructions costs.

The effect of seasonality on the possibility of transporting goods – this criterion assesses the seasonality of the mode of transport. It is worth noting that this mode of transport is not affected by rail modes alone.

Route flexibility in case of unforeseen disturbances – this criterion evaluates the mode of transport ability to change the route of the freight in the event of unplanned disturbances.

As an example could be presented a set of critical points on the road transport route segmente stretch Panevezys-Subacius:

- the positive criteria are: there is an asphalt concrete covering in the stretch when driving on 122 road, the route is shorter, the existing bridge beside Karsakiskis is of bad state, therefore it should be rebuilt in any case. There are no towns driving on 122 road. It is not necessary to build a bridge through traffic on 122 road.
- negative criteria are: 1. It would be necessary to build two culverts and one bridge. 2. The greater part of the route passes through gravel road, it is necessary to expand a turning in Subacius, an electrical pole and cutting trees. 3. It is necessary to mount two culverts.

Conclusion – 1 variant was selected.

It is necessary to pay attention that the route from Seduva to Visaginas is common to all possible variants of heavyweight-outsized cargoe transportation. Differences of routes may emerge due to different weight of transported cargoes or due to a need to reduce the transport flow on the main route.

Conclusions

1. The Unified Criteria System allows to unify various criteria of the process of Oversized and Superheavy Cargo transportation. In this case the decision-making process of the most preferable mode, route and means of transportation for oversized and super heavy cargoes becomes rational, uncomplicated, efficient and comparatively inexpensive.
2. The Unified Criteria System is to create a possibility to recalculate the time and financial cost values into the Unified Criteria Unit, which allows comparison to convert into summing of numbers, dependent on certain features of various transport modes and other circumstances.
3. The Unified Criteria System is an efficient tool for a decision maker who is choosing based on criteria sums between the available alternatives and selecting the most preferable route, transport mode or their combination, loading/unloading processes and even selecting between the planned industrial technologies.

Author contributions:

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